First information on biology of the needlefish *Tylosurus acus imperialis* (Belonidae) off the Tunisian coast (Central Mediterranean)

by

Manel CHAARI* (1), Lobna BOUDAYA (1), Salvatore GANCITANO (2),
Vita GANCITANO (2), Fabio FIORENTINO (2) & Lassâd NEIFAR (1)

Abstract. – Sex ratio, age and growth, length and age at sexual maturity, and spawning season of the Mediterranean needlefish *Tylosurus acus imperialis* (Rafinesque, 1810) off Tunisian coast were investigated. A total of 126 individuals (54 females and 72 males) were sampled. The length weight relationships for females and males were $W = 0.0027\ L^{2.832}$ (s.e.$_a$ ± 0.004; s.e.$_b$ ± 0.238) and $W = 0.0026\ L^{2.827}$ (s.e.$_a$ ± 0.002; s.e.$_b$ ± 0.188), respectively. Otolith reading revealed that females belonged to age groups from 0 to 6 years and males from 2 to 4 years. Most of individuals were of age groups 3. The parameters of the von Bertalanffy growth function were L_∞=123.78 cm (s.e. ± 17.93), k = 0.2 year^{-1} (s.e. ± 0.07) and t_o = -2.28 year (s.e. ± 0.57) for females and L_∞ = 92.28 cm (s.e. ± 5.93), k = 0.5 year^{-1} (s.e. ± 0.15) and t_o = -1.16 year (s.e. ± 0.45) for males. First sexual maturity was estimated at total length of 79.09 ± 0.71 cm for females and 79.18 ± 1.83 cm for males. Gonadosomatic index pattern indicated the spawning season extended from May to July.

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Résumé. – Premières données sur la biologie de la grande aiguille *Tylosurus acus imperialis* (Belonidae) des côtes tunisiennes (Méditerranée centrale).

Le sex-ratio, l'âge et la croissance, la taille et l'âge à la maturité sexuelle et la saison de frai de la grande aiguille *Tylosurus acus imperialis* (Rafinesque, 1810), provenant des côtes tunisiennes, ont été étudiés. Un total de 126 individus (54 femelles et 72 mâles) a été examiné. Les relations taille-masse pour les femelles et les mâles sont $W = 0{,}0027\ L^{2{,}832}$ (e.s.$_a$ ± 0,004; e.s.$_b$ ± 0,238) et $W = 0{,}0026\ L^{2{,}827}$ (e.s.$_a$ ± 0,002 ; e.s.$_b$ ± 0,188), respectivement. La lecture des otolithes indique que les femelles appartiennent à des groupes d'âges compris entre 0 et 6 ans et les mâles entre 2 et 4 ans, la majorité des individus appartiennent au groupe d'âge 3 ans. Les paramètres de croissance de von Bertalanffy sont : L_∞ = 123,78 cm (e.s. ± 17,93), k = 0,2 ans^{-1} (e.s. ± 0,07) et t_o = -2,28 ans (e.s. ± 0,57) pour les femelles et L_∞ = 92,28 cm (e.s. ± 5,93), k = 0,5 ans^{-1} (e.s. ± 0,15) et t_o= -1,16 ans (e.s. ± 0,45) pour les mâles. La taille de première maturité sexuelle a été estimée à une longueur totale de 79,09 ± 0,71 cm pour les femelles et de 79,18 ± 1,83 cm pour les mâles. Le suivi de l'indice gonadosomatique montre que la saison de reproduction s'étend de mai à juillet.

Key words
Belonidae
Tylosurus acus imperialis
Central Mediterranean
Tunisia
Otolithometry
Reproductive biology
Growth

The needlefish (Belonidae) is relatively a small family of Beloniform fishes, having both the upper and the lower jaws extending into long beak mainly filled with sharp teeth (Collette, 2003). Four members of belonid fishes were founded in the Mediterranean Sea (Bauchot, 1987). On Tunisian coast, only three species were reported: *Belone belone gracilis* Lowe, 1839, *B. svetovidovi* Collette & Parin, 1970 and *Tylosurus acus imperialis* (Rafinesque, 1810). The latest species differs from the two others with its largest size, rounded section and absence of gill rakers (Collette and Parin, 1970).

Tylosurus acus imperialis was a valid subspecies of *T. acus*. It was an epipelagic, subtropical, marine species, essentially restricted to the Mediterranean Sea (Collette, 2003). This needlefish, reaching 140 cm of standard length, inhabits offshore waters but can be found in coastal waters (Froese and Pauly, 2011). This species appears seasonally in Tunisian coast, as well in the coastal areas of seas around Sicily (Zava and Fiorentino, 2010), and contributes to the belonids production mainly in the central region of Tunisia. The yield of all belonids species combined represents 0.15% of the total production of pelagic fish and 0.02% of Tunisian fisheries (Anonyme, 2011). No specific data concerning production of *T. a. imperialis* was available. However, according to fishermen, belonids are fished mainly between May and July and beyond this period the production of needlefishes was composed essentially with *B. belone* and *B. svetovidovi* and rarely with some juveniles of *T. a. imperialis* characterized by a melanotic lobe on dorsal fin.

Biological information on *T. a. imperialis* are scarce (Collette and Parin, 1986) and concerns only the reproductive season (Bauchot, 1987; Bello, 1995). Therefore, the present study aims to improve knowledge on reproduction and gives the first information on age and growth of this species in the Central Mediterranean.

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(1) Laboratoire de biodiversité et écosystèmes aquatiques, Département des sciences de la vie, Faculté des sciences de Sfax, BP 1171, 3000 Sfax, Université de Sfax, Tunisie. [lobnaboudaya@gmail.com] [lassad.neifar@gmail.com]

(2) Italian National Research Council (CNR), Institute for Coastal Marine Environment (IAMC), Mazara del Vallo (TP), Italy. [salvatore.gancitano@cnr.it] [vita.gancitano@iamc.cnr.it] [fabio.fiorentino@iamc.cnr.it]

* Corresponding [htchaari.m@gmail.com]

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MATERIALS AND METHODS

A total of 126 *T. a. imperialis* specimens were randomly sampled from artisanal fisheries during May and August between 2004 and 2009 in central and southeastern Tunisian coast. Total length (TL) was recorded to the nearest 0.01 cm. Total body (W), eviscerated body (We) and gonads (Wg) were weighted to an accuracy of 0.01 g. Sex and maturity were determined macroscopically for each specimen. Gonads were preserved in 4% formaldehyde for fecundity studies.

The length-weight relationship was estimated by sex according to the standard allometric equation $W = a * TL^b$.

The relationship coefficients were calculated using non-linear least squares estimation.

Differences between sexes were tested by analysis of covariance (ANCOVA). Before analysis, both length and weight were log10-transformed to achieve linearity.

Length at maturity was described by the classic "ogive" function: $P = 1 / 1 + e^{-r\,(L - L50)}$, where P is the proportion of mature fish at size L, L_{50} is the length at which 50% of specimens were mature and r is the curvature parameter (King, 1995). Ogive parameters were calculated using non-linear least squares estimation.

The gonad somatic index (GSI) was calculated as GSI = (Wg/We) x 100.

A total of 81 otoliths were collected and stored dry. Otoliths were read as whole under water by reflected light against a black background at a magnification of 10X. In case otoliths were thick and opaque, they were included in Implex resin and sectioned transversally through the 'core' using an Isomet low-speed saw (McKurdy *et al.,* 2002). Thin sections (about 0.6 mm) were polished with aluminium oxide powder and observed under transmitted light at a magnification of 10X. The whole otoliths and sections were analyzed by three readers and only the agreed readings were accepted.

Individual age was estimated by counting growth increments, one opaque zone with one translucent zone being considered as annual growth (reflected light). The first translucent ring near the nucleus was considered as larval and not counted for age estimation (Wright *et al*., 2002). Yearly increments are counted considering translucent zones, which are assumed to be laid down in winter. To assign a fish to age group, one entire year is considered for the count when the border of the otolith is translucent. Also, total radius (TR), the distance between the nucleus and the edge of otolith and the distance from the nucleus to the edge of each transparent ring (Ri) were measured. The relationship between TL and TR was determined as the classical linear regression TL = a*TR + b, and result of linear regression was adopted for back-calculation (Francis, 1990). Differences between sexes were tested by analysis of covariance (ANCOVA). The von Bertallanffy equation (VBGF) was established from the back-calculated length at age using parameters of the linear relationship between TL and TR. The growth equation used was in the form:

$$L_t = L_\infty \,(1 - e^{-K\,(t - t_0)}),$$

where: L_t = the total length at age t (years); L_∞ = the theoretical asymptotic total length; k = constant expressing the rate of change in length increments with respect t_0 and t; t_0 = the hypothetical age at length zero.

Parameters of the von Bertalanffy growth equation were estimated by the non-linear approach as implemented in Fisat II (Gayanilo *et al*., 2006).

Differences in the growth parameters by sexes were tested by analysis of the residual sum of squares (ARSS) (Chen *et al.,* 1992), in which F-statistic was calculated as:

$$F = [RSS_p - RSS_s/DF\ RSS_p - DF\ RSS_s] \,/\, [RSS_s/DF\ RSS_s]$$

where RSS_p is RSS of each VBGF fitted by pooled growth data; RSS_s is sum of the RSS of each VBGF fitted to growth data for each individual sample.

For the sake of comparison, the index of overall growth performance φ' proposed by Pauly and Munro (1984) was calculated as: $\varphi' = 2 \log_{10} L_\infty + \log_{10} K$.

RESULTS

Of the 126 needlefishes examined, 54 were females (42.9 %) and 72 were males (57.1%). Sex ratio, estimated as

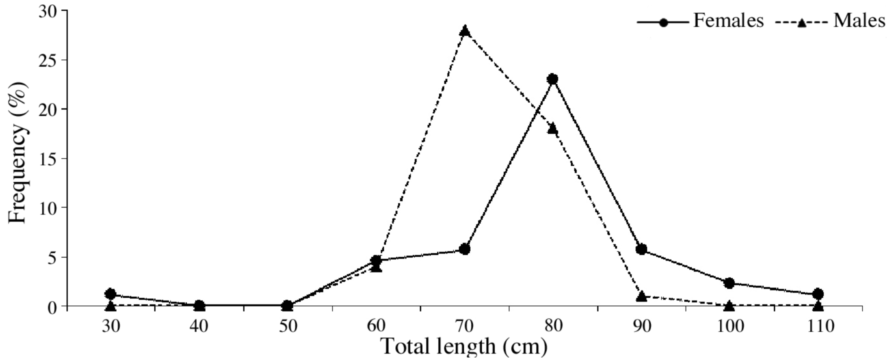

Figure 1. - Length distribution of needlefishes *T. a. imperialis* from Tunisian coast.

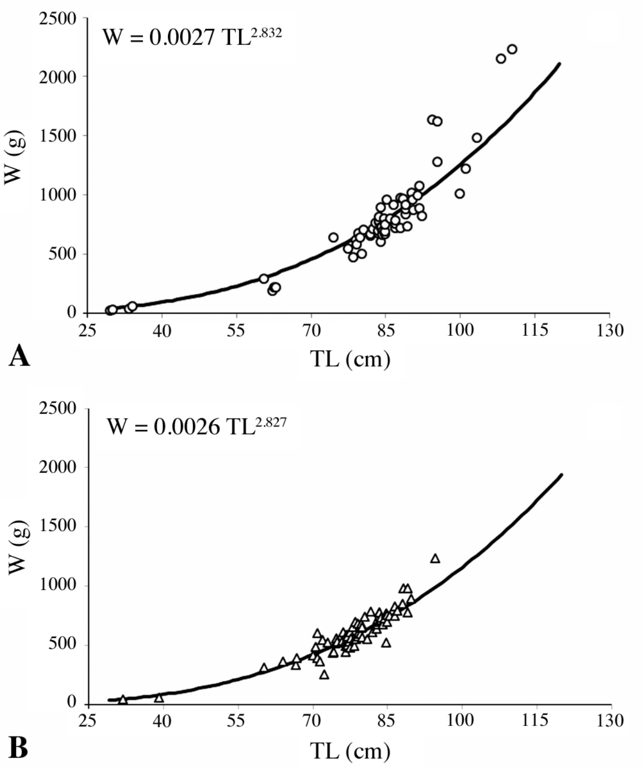

Figure 2. - Length-weight relationships of *T .a. imperialis* from Tunisian coast. **A**: Females; **B**: Males.

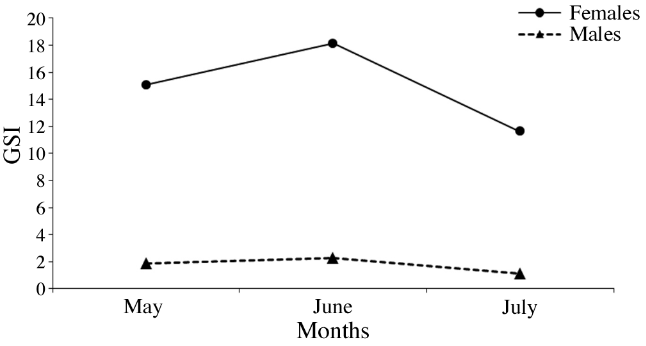

Figure 3. - *T. a. imperialis* gonadosomatic index (GSI) values by sex and months from Tunisian coast.

Table I. - *T. a. imperialis* ANCOVA of TL *vs*. TW relationships. SS: sum of squares; d.f.: degree of freedom; MS: mean squares; F: statistics compared with fish distribution; P: P-value.

	SS	d.f	MS	F	P
Test for heterogeneity of slopes					
Common Residual	0.5672	139	0.004		
Sum Residual	0.5610	138	0.004		
Difference	0.0063	1	0.006	1.541	0.216
Test for differences between intercepts					
Total Residual	1056.38	140	7.546		
Common Residual	0.5672	139	0.004		
Difference	1055.812	1	1055.812	258732.9	< 0.001

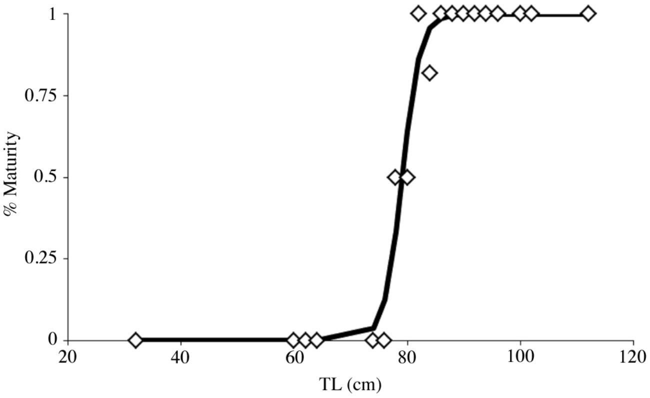

Figure 4. - Length at first maturity of females of *T. a. imperialis*.

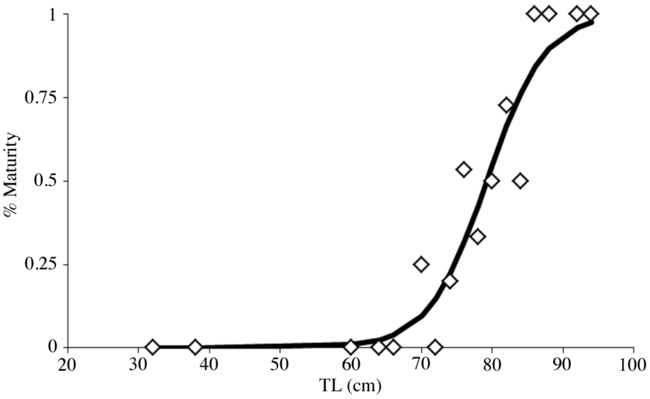

Figure 5. - Length at first maturity of males of *T. a. imperialis*.

females out males, was 0.75, being not different significantly from 1 ($\chi^2 = 2.57$, d.f. = 1, $P > 0.05$). Males outnumbered females in sizes classes 70 and 75 cm TL while females are the most abundant in size class above 85 cm TL (Fig. 1).

Length-frequency distribution shows that the catch was composed mainly by individuals between 70 and 80 cm TL. The total length ranged from 29.7 to 110.5 cm for female and from 31.8 to 94.7 cm for males. The range was smaller for males than for females (Fig. 1).

Total weight varied from 20.7 to 2,231 g with a mean of 715.4 ± 94.2 g for female and from 37.7 to 1,226 g with a mean of 586.7 ± 43.4 g for males respectively. Differences in the length-weight relationships between males and females were shown in figure 2A, B. Significant differences were found between sexes in the length-weight relationships using covariance analysis (Tab. I).

Mature females were observed from May to July. In this period almost 75% of female were sexually mature. The GSI results revealed that the spawning season of the needlefish *T. a. imperialis* from Tunisian coast appeared to be from

May to July with a peak in June. Similar pattern was shown for males but the value of GSI result lower than to female (Fig. 3).

Maturity at length ogives for females and males are reported in figures 4 and 5. Females *T. a. imperialis* reached 50% sexual maturity at 79.09 ± 0.71 cm (r = 0.63 ± 0.25) of total length and male at about 79.18 ± 1.83 cm (r = 0.24 ± 0.10) of total length.

Measured with an ocular micrometer, oocytes numbers in the ovaries varied from 16,075 to 34,559 with a mean value of 2 mm in diameter.

Concerning ageing, otoliths of *T. a. imperialis* were not difficult in readings, with well-visible altering opaque and translucent zones (Fig. 6). Out of 81 otoliths analyzed, only 13 (16%) were unreadable. The relationships between total otolith radius and total length were linear (R = 0.83) (Fig. 7A, B).

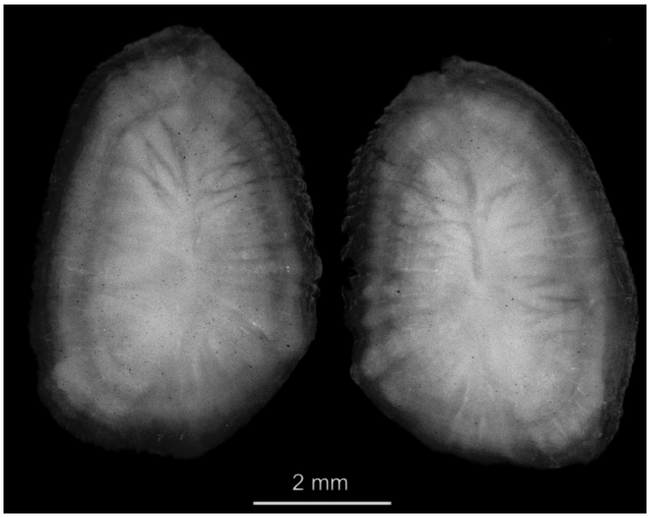

Figure 6. - Otolith of *Tylosurus acus imperialis*.

Table II. - Length frequency distribution of total samples and component age groups of *T. a. imperialis* from Tunisian coast. –: none caught.

Total length (cm)	Age groups (years)							Total
	0	1	2	3	4	5	6	
30-39.9	1	–	–	–	–	–	–	1
40-49.9	–	–	–	–	–	–	–	–
50-59.9	–	–	–	–	–	–	–	–
60-69.9	–	2	5	–	–	–	–	7
70-79.9	–	–	8	21	1	–	–	30
80-89.9	–	–	1	28	6	–	–	35
90-99.9	–	–	–	2	3	–	–	5
100-109.9	–	–	–	–	2	–	–	2
110-119.9	–	–	–	–	–	–	1	1
Number of fish	1	2	14	51	12	0	1	81
Frequency (%)	1.23	2.47	17.28	62.96	14.81	0.00	1.23	

Age of females were from 0 to 6 years for a total length from 29.7 to 110.5 cm with a mean of 80.5 ± 4.4 cm. Males were between 2 to 5 years, ranging from 31.8 to 94.7 cm TL with a mean of 76.8 ± 2.5 cm. For both sexes, age group 3 was dominant (63%) (Tab. II).

The estimated growth parameters and the backcalculated mean total length-at-age data were given in tables III, IV and figure 8. The Chen's test showed that significant difference by sexes in growth pattern was detected (Tab. V). Also, using covariance analysis, significant differences were found between sexes in the relationship between TL and TR (Tab. VI).

The age that covers more than 50% of all specimens is considered as the first maturity age. Consequently, in Tunisian coast, females and males *T. a. imperialis* reached first maturity between 2 and 3 years (inverse VBGF).

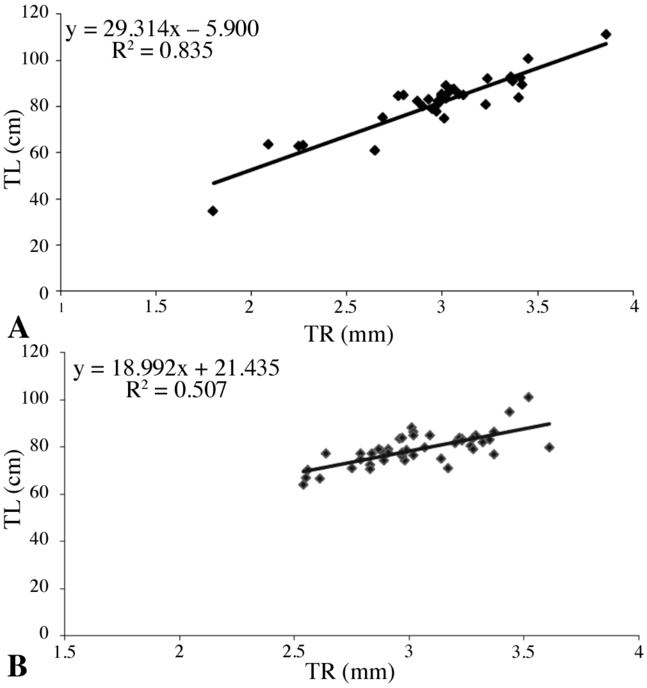

Figure 7. - Total otolith radius (TR) *vs*. total body length (TL) relationships of *T. a. imperialis* from Tunisian coast. **A**: Females; **B**: Males.

Table III. - Backcalculated mean total length at successive ages of *T. a. imperialis* from Tunisian coast.

Age groups (years)	Calculated mean total length (cm)					
	1	2	3	4	5	6
1	59.18	–	–	–	–	–
2	60.49	73.29	–	–	–	–
3	59.67	72.66	80.35	–	–	–
4	61.28	73.15	80.74	86.02	–	–
5	–	–	–	–	–	–
6	66.47	79.79	86.58	91.36	–	99.40
Mean length (cm)	61.41	74.72	82.55	88.68	–	99.40

DISCUSSION

The current study provides the first information on age and growth of the needlefish *T. a. imperialis* from Tunisian coast and confirmed the knowledge on reproduction cycle of this species from Mediterranean and Adriatic Sea (Bauchot, 1987; Bello, 1995).

The catch structure lengths of *T. a. imperialis* off Tunisian coast showed that majority of individuals were in the size range of 70 and 80 cm and in age group 3. These needlefishes were composed by almost equal percentage of males and females, which were caught mainly between May and July. This period coincides with the spawning season of this species. Estimated total length at first maturity of *T. a. imperialis* off Tunisian coast was around 79 cm (between 2 and 3 years) for males and females. Thus, the majority of fishes caught by artisanal fisheries were mature adults. It seems that this species congregates seasonally on coasts for spawning. In fact, horizontal migration appears to be common in this species. According to Froese and Pauly (2011), this species inhabits offshore waters, but is also found in coastal waters. Moreover, migration into coastal waters for spawning is known in belonid species. Indeed, Whitehead *et al.* (1986) reported that the garfish *Belone belone* spawns in coastal waters from May to June in the British Isles, February to May in Algeria, and April to September in the Black Sea. Dorman (1989) mentioned that garfish migrates into the coastal waters of the British Isles and the northern Europe every summer for spawning.

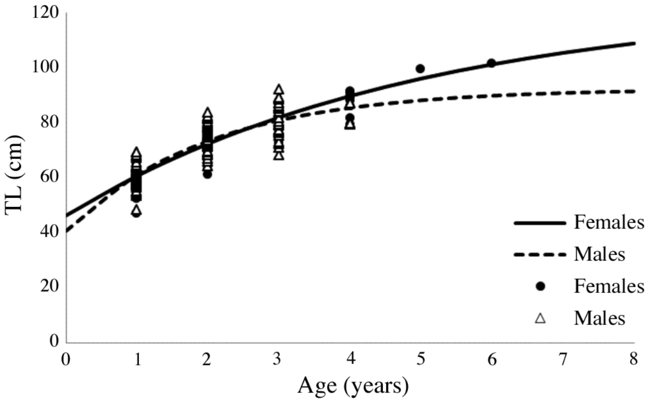

Figure 8. - Growth curve and back calculated length at age by sex of *T. a. imperialis* from Tunisian coast.

Table IV. - Growth parameters of von Bertalanffy model of *T. a. imperialis* from Tunisian coast. φ': growth performance index; L_∞: asymptotic total length; K: growth curvature parameter; t_0: the hypothetical age at length zero.

Parameters	Females	Males	Combined
L_∞	123.78	92.28	122.03
K	0.20	0.50	0.20
to	-2.28	-1.16	-2.49
φ'	3.49	3.63	3.47

Table V. - Sex comparison of growth modeled by VBGF by means of RSS of *T. a. imperialis*. RSS_p: RSS of each VBGF fitted by pooled growth data; RSS_s: sum of the RSS of each VBGF fitted to growth data for each individual sample.

RSS_{pooled}	5343.66	RSS_{sample}	5142.25	F	2.98
DF_{pooled}	231	DF_{sample}	228	p	0.03

Table VI. - *T. a. imperialis* ANCOVA of TL vs. TR relationships. SS: sum of squares; d.f.: degree of freedom; MS: mean squares; F: statistics compared with fish distribution; P: P-value

	SS	d.f	MS	F	P
Test for heterogeneity of slopes					
Common Residual	0.05490	77	0.000713		
Sum Residuals	0.05490	76	0.000722		
Difference	0.00003	1	0.000030	0.0455	0.8316
Test for differences between intercepts					
Total Residual	17.197	78	0.220		
Common Residual	0.055	77	0.001		
Difference	17.142	1	17.142	24036.59	< 0.001

Table VII. - Summary of growth performance of different belonid species.

Species	Author	Locality	φ'		
			Females	Male	Sexes combined
B. belone	Uçken *et al.* (2004)	Aegean Sea	2.99	2.99	2.97
B. b. euxeni	Samsun *et al.* (2006)	Black Sea	–	–	2.86
B. belone	Kalayci and Yeşilçiçek (2012)	Black Sea	3.09	3.02	–
T. a. imperialis	This study	Tunisian coast	3.49	3.63	3.47

The fluctuation of sex ratio showed that spawning migration of *T. a. imperialis* started by a rush of males, only females were present at the end of migration. This pattern of sex ratio variation is known in migratory species (Kartas and Quignard, 1984). According to these authors, the rise of females to spawning is usually later than males. Similarly, Roule (1924) observed that the number of females is low compared to that of males at the beginning of migration of *Alosa agone* (Clupeidae), the proportion of males is double or triple to that of females at the time of spawning. However, little information was known about migration patterns and behavior outside of the spawning season (Hunter *et al.*, 2003). The migratory route of *T. a. imperialis* in the rest of the year is not clear.

Our results show that the needlefish *T. a. imperialis* had a summer spawning period and confirm findings of other authors. Indeed, Bauchot (1987) reported that *T. a. imperialis* spawns in summer in Mediterranean Sea. Bello (1995) confirmed this statement in the south Western Adriatic coast. Summer spawning seems to be typical in other *T. acus* spp. *T. a. melanotus* have a spawning season extending from April to August with a peak in June in South Western Thaiwan (Yih-Yia and Yu-Hsin, 2011).

Concerning age and growth, this study provides the first information on the growth of this needlefish. The oldest individual recorded in our study was a 6 year old female. The length at age and von Bertalanffy parameter estimates showed that *T. a. imperialis* is a fast-growing and non-long living species, like the other belonid species *Belone belone*. Our material shows that females have a slower growth rate and larger maximum length and age than males. A comparison of female and male φ' values (φ' = 3.49 and φ' = 3.63, respectively) shows that the population of *T. a. imperialis* from Tunisian coast had a fast growth performance compared with other belonids (Tab. VII).

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